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A WIDE-BAND VIDEO NOISE SOURCE

50 KC to 10 MC

[UNCLASSIFIED TITLE]

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Countermeasures Branch
Radio Division

April 2, 1957

NAVAL RESEARCH LABORATORY
Washington, D.C.

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ABSTRACT

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A new wide-band (10-Mc) random video noise source for use in countermeasures application has been derived from a magnetron-type counter tube (Type 6700).

Its spectrum shows a major improvement over the spectrum of the commonly employed 6D4 gas triode. The main weaknesses of the two video noise sources used until now in countermeasures are lack of uniform spectral distribution of frequencies over a sufficient bandwidth and lack of adequate output power. Spectra of the commonly used 6D4 tubes are nonuniform and do not extend over a sufficiently broad band. The 931 phototube requires careful adjustment of the auxiliary light source, needs high voltage on the tube elements (one kilovolt), and produces an output of only a few millivolts, which necessitates the use of high-gain, broad-band preamplifiers.

The 6700-type counter tube has been investigated as a noise source, and it shows a uniform spectrum from 50 kc to 7 Mc of ±1.2 db variation (±2.8 db variation from 50 kc to 10 Mc). It has an output voltage of between 0.25 and 0.5 volt rms and a primary power requirement of 8 ma at 150 volts.

An experimental plug-in 10-Mc video noise source utilizing the counter tube has been constructed for use in a modulator. It provides one volt rms output and is flat from 50 kc to 10 Mc with a ±2.8 db variation. A second such unit, to be used as a laboratory noise source, has been built with the addition of a variable low-pass filter and provides selectable bandwidths of 1, 2, 5, and 10 Mc.

The 6700 shows a noise spectrum bandwidth several times that of a 6D4, and is only slightly larger than the 6D4 (with assembled magnet) and has a reputed life expectancy of several thousand hours.

It is believed that the efficiency and perhaps spectrum bandwidth and amplitude characteristics of the 6700 could be improved over its presently acceptable state, if the parameters of the tube were optimized to provide a simplified design for specific application to electronic countermeasures.

PROBLEM STATUS

This is an interim report; work is continuing.

AUTHORIZATION

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INTRODUCTION

The present tendency to shorten the pulse length of radar transmitters in order to obtain increased resolution requires a corresponding increase in the bandwidth of their associated receivers. To design radar equipment with a 0.1-microsecond pulse length is common engineering practice, and the tendency is to provide greater bandwidth in the receiver than that given by the usual classic relation for best signal-to-receiver noise ratio, $B = 1/t$, where B is the bandwidth in megacycles and t is the pulse length in microseconds. This may be justified somewhat by the advent of low-noise, wide-band traveling-wave tubes and their use as preamplifiers.

Simple principles indicate that countermeasures equipment should be capable of introducing confusion-signal components corresponding to the acceptance bandwidth of such receivers, although admittedly, the video noise bandwidth of a confusion or jamming signal is but one of the many factors involved in countermeasures effectiveness. The continued search for a reliable noise source emphasizes either that video noise sources are difficult to construct or that a basic weakness exists in those used at present. It appears that study of a better noise source with at least 10 megacycles bandwidth can be justified on the basis of present and projected equipment specifications.

PRESENT VIDEO NOISE SOURCES

Video noise is usually provided from one of two sources: gas triodes with transverse magnetic field such as the type 6D4, or multistage photomultiplier tubes such as the type 931. The merits and disadvantages of these noise sources are well known, but will be reviewed briefly.

The 6D4-type tube has modestly low voltage power requirements and sufficient noise voltage output, provided the spectrum be reasonably flat. A peak occurs between 0.7 and 1 megacycle, however, with the amplitude falling off more on the high-frequency side, being 30 to 45 decibels down at 5 megacycles. This requires a band rejection filter with sufficient insertion loss at the peak frequency to provide a complementary response to that of the spectrum, thereby providing a flat output that may be amplified to a suitable level for use in equipment modulators. Because of nonuniformity within the 6D4 family, the design of such a filter must be a compromise that is unsatisfactory for even a good 5-megacycle noise source.

The 931 and related tubes have good spectral characteristics when correctly applied, but require approximately one kilovolt across the small pin separation of the tube base, necessitating pressurization if high altitude or excess humidity is encountered. The illuminating intensity of the small lamp used to excite the photoemissive surface must be adjusted critically, and the filament must be powered with direct current because the amplification of one or more amperes per lumen precludes alternating-current operation for most uses involving video noise. The main disadvantage of this type tube, however, is that only a few millivolts noise output is available, necessitating a wide-band video amplifier of 40 to 60 decibels gain to provide one volt of usable noise.

INVESTIGATION OF THE 6700 COUNTER TUBE AS A VIDEO NOISE SOURCE

In early 1956 during study on a memory-circuit project the author became aware of the manufacturer's specifications of noise for the type 6700 counter tube. Because the noise level was detrimental to its intended application in the memory circuit, a tentative study was instigated to determine the spectral content, whose nature had not been specified. A quick examination with a visual video analyzer constructed several years ago* disclosed the spectrum of the 6700 to be quite uniform throughout a video range extending to 10 megacycles, with a broad maximum between 3 and 5 megacycles and a gradual decline in amplitude of approximately 5 to 6 decibels at 10 megacycles. An output of from 1/4 to 1/2 volt rms and a modest power requirement of 7 to 10 milliamperes at 150 volts indicated that what may have been a decided disadvantage for use in a memory circuit might be turned to some practical use as a much needed wide-band video noise source. In addition, the manufacturer claims that due to its simple internal construction the tube has a life of several thousand hours as a counter, and it is believed that the tube should have an equally long life as a noise source since the rated dissipation is not exceeded in this application. Extended tube-life runs have not been made however.

Although a theoretical study of the state within the tube under conditions that produce noise will not be undertaken here, a description of the tube's internal construction and use as a counter will be outlined in brief. The type 6700 counter tube, originally a Swedish invention† and later improved by Haydu,‡ consists of an indirectly heated cathode surrounded by 30 elements geometrically arranged in 10 groups (Fig. 1). Each group is composed of a target, a spade, and a grid, the spade and grid being interposed between the target and cathode. A permanent magnet furnishes a field of 450 gauss perpendicular to the electron flow between the cathode and the other tube elements. The spade has a negative-resistance characteristic due to the crossed magnetic and electric fields, and under static conditions the tube is at current cutoff. If any spade potential is lowered below a critical value, the altered field conditions cause the target to become conducting. Lowering the potential of the grids, other conditions remaining equal, causes the electron beam to shift to the next target position. This can continue around the tube, providing a digital-sequence action which may be cascaded to additional tubes to provide a practical counter.

DESIGN PARAMETERS FOR THE NOISE SOURCE

When the 6700 tube is used as a noise source, the potentials on the tube elements are not greatly altered from those of its application as a counter. The spade current is reduced to limit the target current to a safe value. The target, from which the noise is taken, is a constant current element of rather high impedance, and the coupling of this element to a following amplifier must be treated accordingly. Using the nominal target capacitance of 5 $\mu\mu$f, computations for networks with inductive elements to reduce shunt loading effects indicate a tendency toward undesirable ringing. Whether this is due to any reflected

*Griffin, F. T., "Video Presentation Analyzer, 50 kc to 10 Mc," NRL Report 4664 (Unclassified), March 1956

†Alfven, H., Lindberg, L., Malmfors, K. G., Wallmark, T., and Astrom, E., "Theory and Applications of Trochotrons," Trans. Roy. Inst. Tech., Stockholm, No. 22 (1948); Bjorkman, J., and Lindberg, L., "Development of Trochotrons," Trans. Roy. Inst. Tech., Stockholm, No. 80 (1954)

‡Haydu Brothers of New Jersey, Plainfield, N. J., a subsidiary of Burroughs Corporation

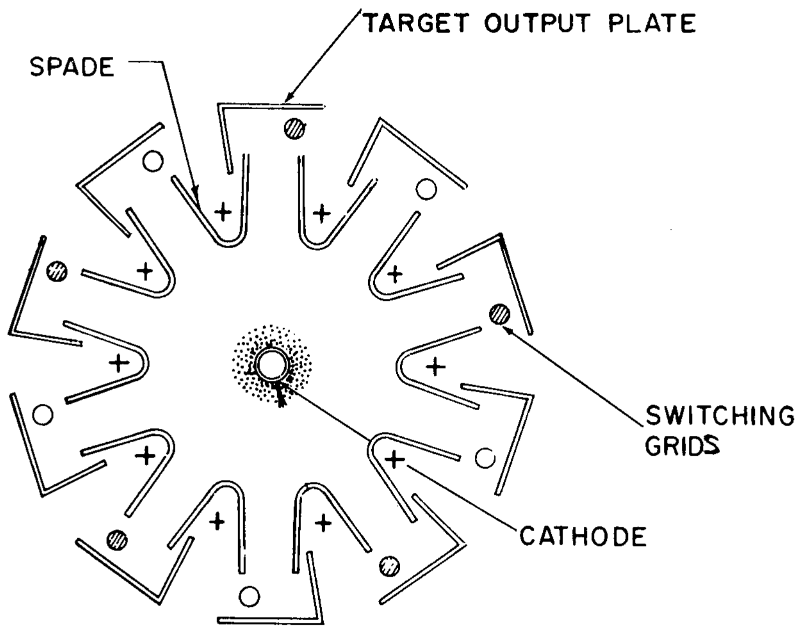


Fig. 1 - The type 6700 counter tube

"pulling" effect was not determined conclusively, but this is strongly suspected because correlated and feebly damped frequencies are present when such a network is used and absent when the target is directly connected to a cathode follower, and then to the following amplifiers. Admittedly this diminishes the initial output somewhat. Classical compensation networks using 30- to 50- millimicrosecond rise-time constants may follow the cathode follower without appreciable deleterious effects on the character of the noise.

The spectra of several sample tubes showed some variations (Fig. 2), but these are quite minor in comparison to variations shown by 6D4 tubes. Figure 3 shows a direct comparison of the type 6D4 spectrum (a) with the 6700 spectrum (b). The output power is approximately directly proportional to the target current squared. The maximum peak frequency decreases with current, although the peak is very broad. A sufficient number of tubes were not available to give a thorough statistical study, but at the high-frequency end a maximum variation of 3 decibels was noted at 10 megacycles with each tube operating at the same maximum target current of 7 milliamperes. A study of the spectrum of a typical tube disclosed that a ±30 percent change in grid voltage (from a nominal +30 volts) produced only negligible effects. External field variations in general did not give as pronounced an effect as had been expected, although it is hoped to extend this part of the investigation in the future to include wider variations of the various parameters such as the electric field of the other target and spade elements. Magnetic field values of 300 and 550 gauss were applied, with the spade voltage adjusted to give the specified one-watt maximum dissipation of the target. These field values do not depart excessively from the specified value of 450 gauss (which was checked by measurements), but was sufficient, it was thought, to indicate any trends and yet remain within the practical limits of possible future alteration by the manufacturer specifically for noise use. When the lower field value was applied, the peak-amplitude frequency of the spectrum decreased in value by approximately one megacycle and the high-frequency noise amplitude also decreased,

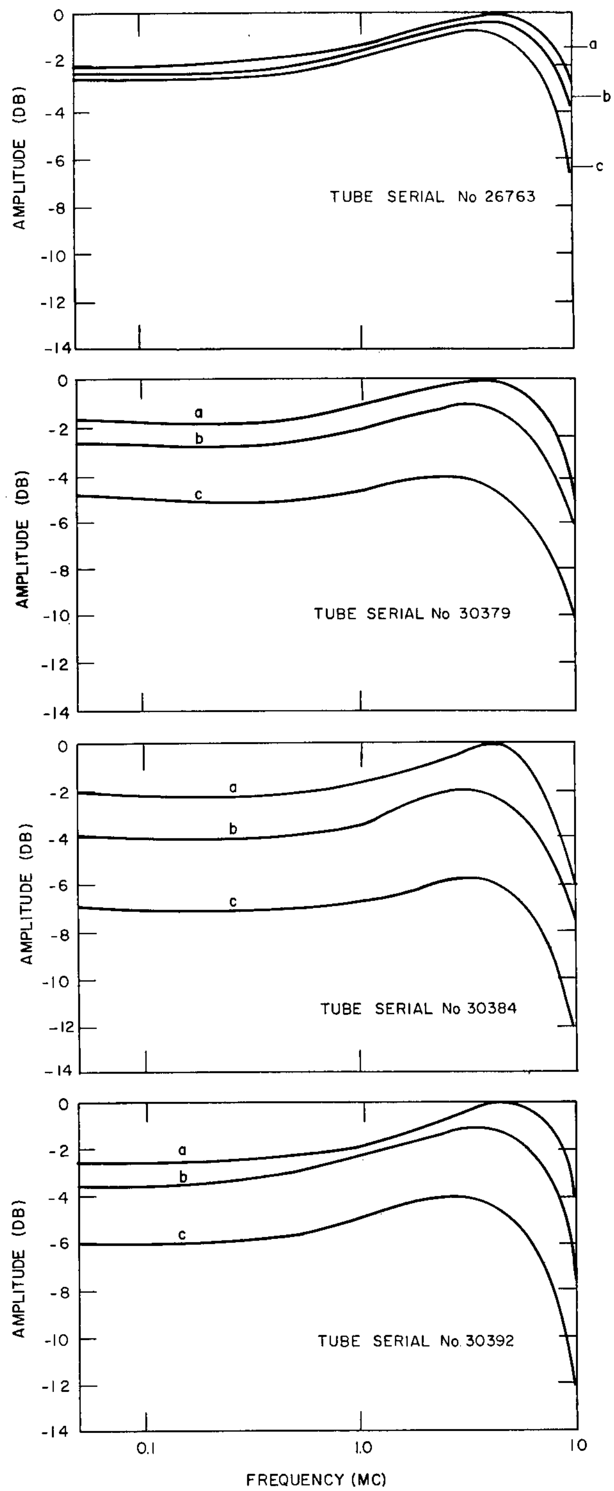


Fig. 2 - Noise spectra of sample 6700 type counter tubes. Target currents were (a) 7 milliamps, (b) 5 milliamps, and (c) 3 milliamps

although by only one decibel or so at 10 megacycles. The higher field value did not produce any startling results, although during these magnetic field changes the electric field was not varied to any great degree. Lack of time prevented experiments with divergent magnetic fields, but it is hoped to try such experiments at a later date.

In a practical circuit some method must be provided to cause the correct target to draw current. Figure 4 shows a neon tube, N1, biased at approximately -20 volts and connected to a divider in the spade circuit of the correct target. When the voltage across N1 reaches 90 to 105 volts, the gas discharge brings the spade to a lower voltage than any other spade and thus causes the desired target to conduct. The same function may be accomplished manually by grounding this spade with switch SW1, obviating a requirement for a negative voltage. The second neon tube, N2, is to indicate that the spade is at a negative voltage and a voltage exists across R1. This method of indicating noise output was more infallible than the existence of current in the target alone, since it was found that a combination of conditions could exist, even though unstable, where target current existed and its corresponding spade was at high positive potential, but where no noise output appeared.

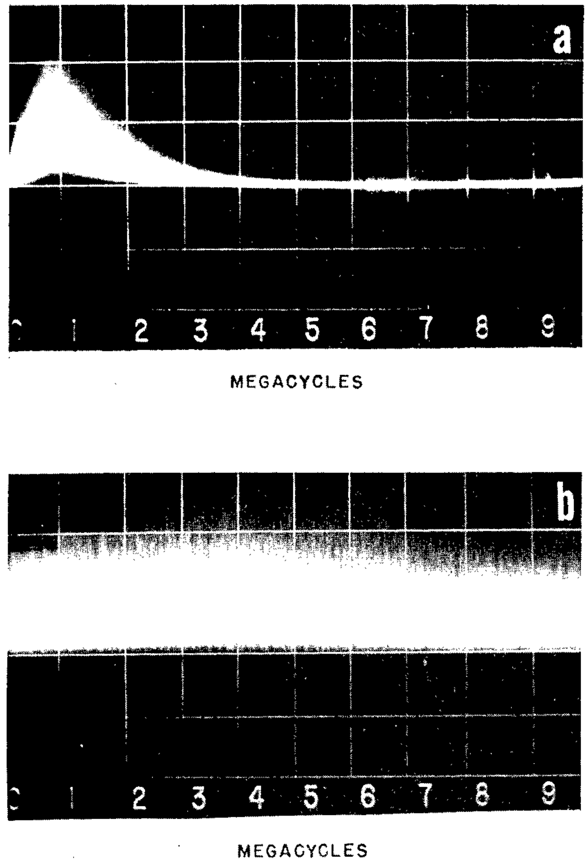


Fig. 3 - Comparison of the 6D4 spectrum with the 6700 spectrum

TERMINAL APPLICATION

A practical noise unit composed of three envelopes including the 6700 (the circuit shown in Fig. 4) has been fabricated using a chassis 4 inches by 2 inches by 1.5 inches (Fig. 5), and this volume could probably be reduced by printed-circuit techniques. This plug-in noise source provides one volt rms of noise, and the cathode-follower output is flat within 2 decibels from 50 kilocycles to 7 megacycles and down 4.8 decibels (from the peak value) at 10 megacycles (Fig. 6). It is now being incorporated into an experimental wide-band modulator. The same unit with a variable-frequency cutoff filter (Fig. 7) and attached power supply has been built as a laboratory noise source (Fig. 8). The filter permits the selection of noise bandwidths of 1, 2, 5, and 10 megacycles.

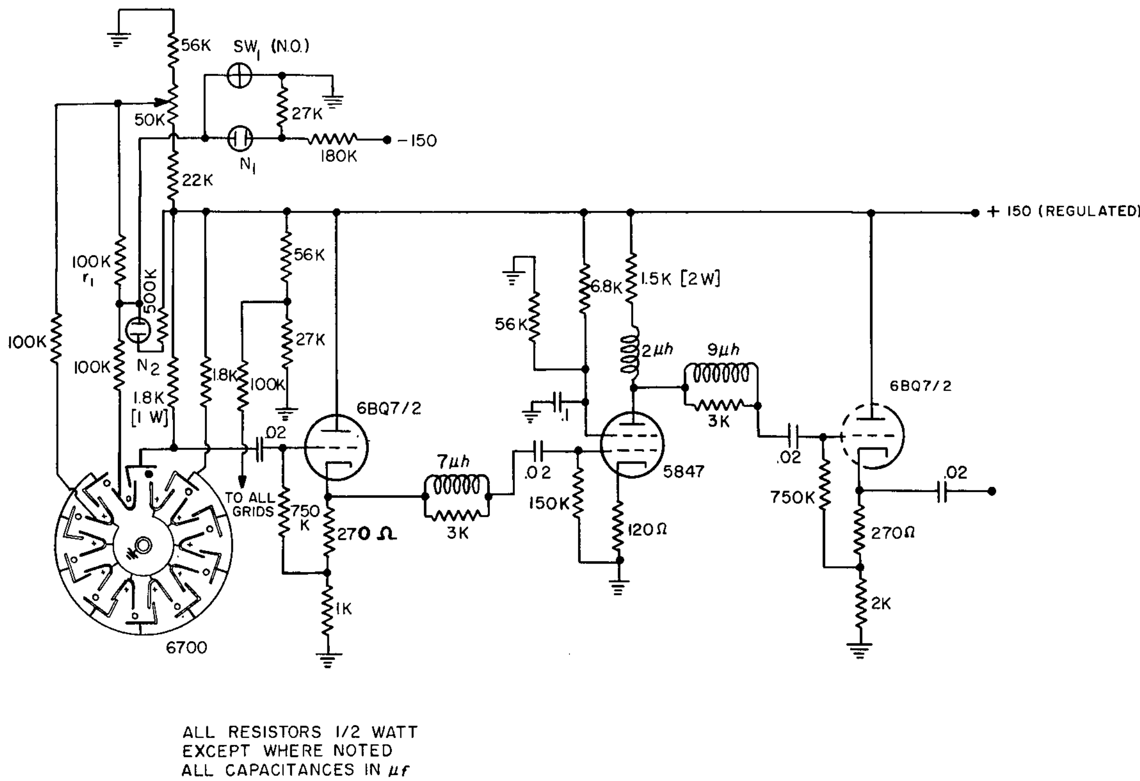


Fig. - 4 A 10-megacycle noise source utilizing the type 6700 counter tube

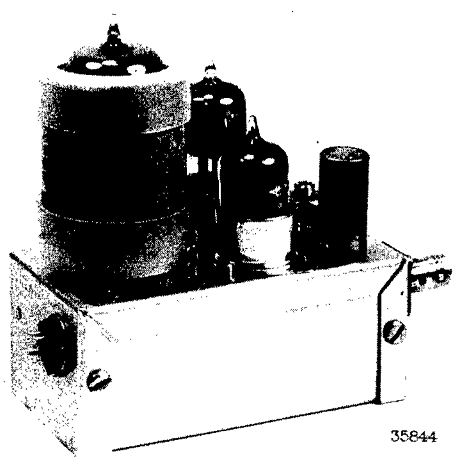


Fig. 5 - Plug-in version of the 10-megacycle video noise source diagrammed in Fig. 4

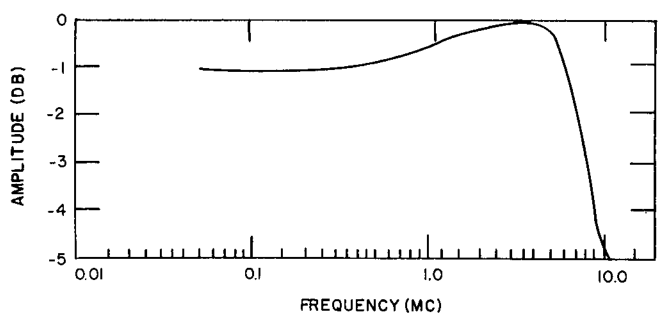
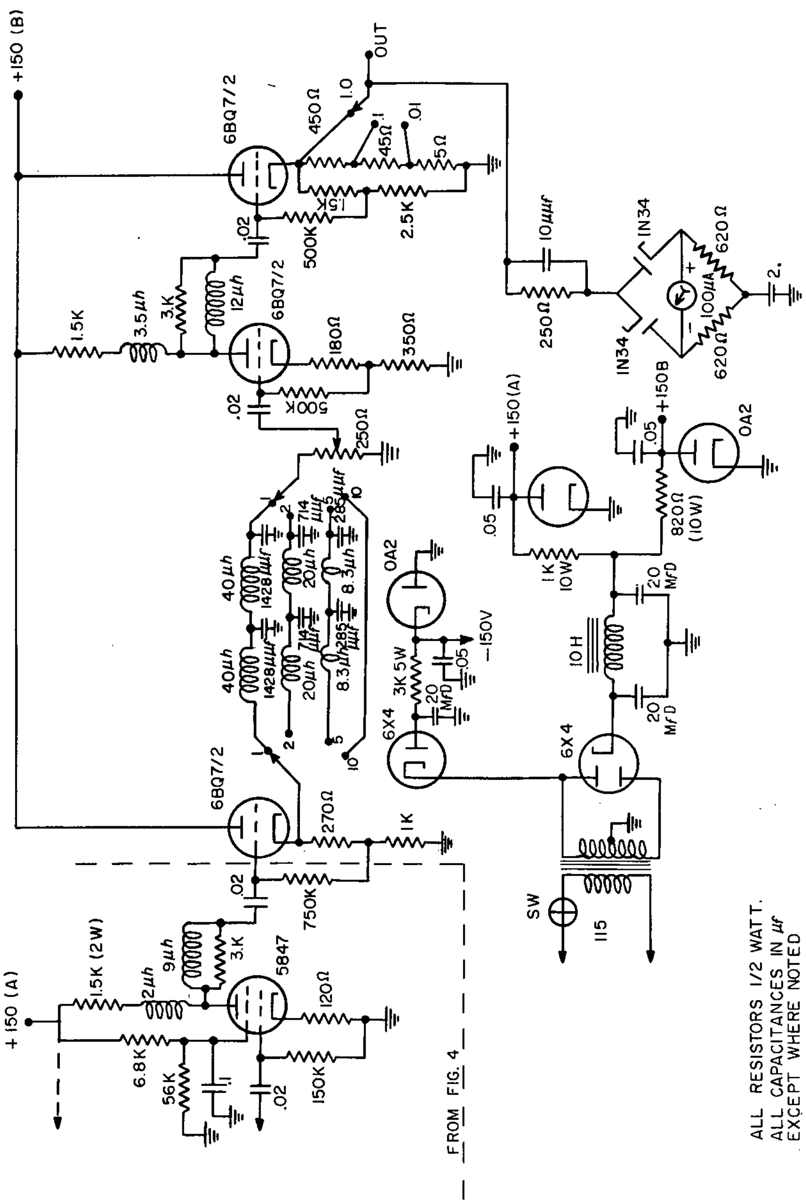


Fig. 6 - Spectrum of one-volt rms plug-in version of the 10-megacycle video noise source



ALL RESISTORS 1/2 WATT.
ALL CAPACITANCES IN μf
EXCEPT WHERE NOTED

Fig. 7 - Terminal, variable-frequency, low-pass filter

Fig. 8 - A laboratory version of the 10-megacycle video noise source, including the filter section of Fig. 7 and built-in power supply

CONCLUSION

The type 6700 counter tube offers a practical improvement over the tubes presently employed for the generation of wide-band video noise. Its bandwidth exceeds by many times that of the gas-filled 6D4 tube commonly used, and has a predicted life expectancy of several thousand hours. It fills the needs of wide-band systems which have modulator requirements for random video noise with frequencies up to and including 10 megacycles.

As the development of this tube (like the 6D4) was not originally undertaken specifically as a noise source, it is believed that the efficiency and perhaps spectrum bandwidth and amplitude characteristics could be improved, even over its presently acceptable state if the parameters of the tube were optimized for noise purposes. Such variations as the increase in cathode and target size for increased power output, and the removal or simplification of certain spade and grid elements that do not contribute to the tube's function, in the present application, would reduce the number of glass-to-pin seals from the present (27) to a more modest number, as well as decrease the tube's cost. Such a program would, in addition, avoid another embarrassing situation such as once occurred when the manufacturer of the 6D4 tube "engineered" the noise out of this tube – making it unsuitable for countermeasures use. This program would ensure a specific noise tube that would have a defined spectral distribution and voltage output for countermeasure application.

* * *

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